REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
02-09-2015	Final Report	20-Feb-2012 - 19-Feb-2015

4. TITLE AND SUBTITLE
Final Report: LoFASM: A Low Frequency All Sky Monitor for Radio Transients and Student Training

5a. CONTRACT NUMBER
W911NF-12-1-0062

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
206022

6. AUTHORS
Fredrick Jenet, Teviet Creighton, Richard Price

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES
University of Texas at Brownsville/Texas Sc
One West University Blvd

Brownsville, TX 78520 -4933

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSOR/MONITOR'S ACRONYM(S)
ARO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
60495-EL-REP.6

12. DISTRIBUTION AVAILIBILITY STATEMENT
Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT
The Low-Frequency All-Sky Monitor (LoFASM) is an innovative new radio astronomy observatory. Designed and built by faculty and by graduate, undergraduate, and high-school students, it is the first instrument specifically designed for the detection of low-frequency (10 to 88 MHz) astrophysical radio transients. It consists of four geographically-separated stations, each comprising 12 phased array dipole antennas. All four stations have now started taking data. The observatory has also been a vital recruiting and training tool for physics students from the South Texas region. LoFASM was instrumental in establishing the Spacecraft Tracking and Astronomical

15. SUBJECT TERMS
Radio astronomy, phased array, radio transients, student training

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Fredrick Jenet
UU	UU	UU	UU		19b. TELEPHONE NUMBER
					956-882-5131

Report Title

Final Report: LoFASM: A Low Frequency All Sky Monitor for Radio Transients and Student Training

ABSTRACT

The Low-Frequency All-Sky Monitor (LoFASM) is an innovative new radio astronomy observatory. Designed and built by faculty and by graduate, undergraduate, and high-school students, it is the first instrument specifically designed for the detection of low-frequency (10 to 88 MHz) astrophysical radio transients. It consists of four geographically-separated stations, each comprising 12 phased array dipole antennas. All four stations have now started taking data. The observatory has also been a vital recruiting and training tool for physics students from the South Texas region. LoFASM was instrumental in establishing the Spacecraft Tracking and Astronomical Research into Gigahertz Astrophysical Transient Emission (STARGATE) project, a public-private partnership between UTB's Center for Advanced Radio Astronomy and SpaceX, focused on RF technology innovation and commercialization. Where this DoD grant funded the deployment and commissioning of LoFASM, an NSF grant has recently been secured to fund its ongoing scientific operations.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
James Murray	0.00	
Louis Dartez	1.00	
Jing Luo	0.00	
Emma Handzo	0.00	
FTE Equivalent:	**1.00**	
Total Number:	**4**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
Yan Wang	0.00
FTE Equivalent:	**0.00**
Total Number:	**1**

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Teviet Creighton	0.07	
Fredrick Jenet	0.00	
Richard Price	0.00	
Volker Quetschke	0.00	
FTE Equivalent:	**0.07**	
Total Number:	**4**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED	Discipline
Andrew Danford	0.00	Physics
Andres Hernandez	0.00	Physics
Keith Boehler	0.00	Physics
Aldo Fonrouge	0.00	Physics
FTE Equivalent:	**0.00**	
Total Number:	**4**	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 1.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 1.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 1.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 1.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:...... 1.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

List of Figures:

Statement of Purpose:

This grant funded the construction and initial commissioning of the Low-Frequency All-Sky Monitor (LoFASM), the first observatory specifically designed for the detection of astrophysical radio transients. Its simple design encourages student participation, making it not only a cutting-edge scientific instrument, but also a recruiting and training tool for students entering Science, Technology, Engineering, and Mathematics (STEM) fields. It is built and operated by the Center for Advanced Radio Astronomy (CARA) of the University of Texas at Brownsville, a Hispanic-serving institution located in one of the poorest regions of the country.

Summary of Results:

LoFASM now consists of four geographically-separated stations: LoFASM I at Port Mansfield, Texas; LoFASM II at the north arm of the Very Large Array near Socorro, New Mexico; LoFASM III at the Green Bank Radio Observatory in West Virginia; and LoFASM IV at the Goldstone Deep Space Communications Complex in California (see Fig. 1). This separation places each station in a different terrestrial radio noise environment (see Fig. 2), allowing observers to discriminate between extraterrestrial radio bursts and those of local terrestrial origin.
Each station comprises 12 dipole antennas in a phased array: the antenna feeds can be combined in such a way as to maximize sensitivity from overhead while suppressing signals incident from the horizontal plane; or vice-versa. This provides a further tool for discriminating astrophysical signals from terrestrial noise. Each station is sensitive to a large swathe of the sky, and is capable of 24/7 operation, making the observatory optimal for searching for astrophysical radio transients.

During the first two years of the grant, all hardware was purchased and installed at all four sites. The last year of the grant focused on commissioning, improving reliability, and testing sensitivity. All four sites have taken data, and initial sensitivity tests have shown that the instrument can operate at its design sensitivity, limited by the Galactic radio background (see Fig. 3). Subsequent operations, however, demonstrated that certain back-end electronics elements were more delicate than expected, precluding 24/7 operation at all sites. After redesign and repair of the back-end electronics, two sites have been restored to 24/7 operation, with the remaining two expected to come back online in the next few months.

Many students have worked on LoFASM over the course of this grant, optimizing its design, deploying the hardware, and devising and building the back-end electronics and data analysis system. Technical reports authored by these students have been listed in the Presentations sections of the annual reports. A total of 10 high school students, 16 undergraduate students, and 5 graduate students (including two former undergraduates) have worked on the project. Six of the undergraduates have graduated and are pursuing graduate degrees in STEM fields. One of the graduate students received his MS and is continuing to do his PhD research with the project. One graduate student has received his PhD and is pursuing postdoctoral research in a related field, while still maintaining involvement with LoFASM. The LoFASM project has been instrumental in transforming a physics department that used to graduate just one undergraduate every year or two, into one of the top producers of Hispanic physicists in the nation.

During the months following the expiration of this grant, we have ramped up our efforts to develop radio-frequency interference (RFI) mitigation techniques and perform scientific analysis of the data produced by LoFASM. In collaboration with a UT Dallas faculty member in the field of radio engineering, we have recently been approved for a 3-year $670,000 grant from the NSF to perform this research. Thus, in addition to its primary goal of promoting the development of a diverse workforce trained in areas relevant to the DoD, this instrument has proven itself to be an important scientific instrument capable of securing independent funding for its ongoing operation.

LoFASM has also played a substantial role in attracting Space Exploration Technologies Corporation (SpaceX) to build a commercial orbital launch facility in South Texas. As a result of interactions between SpaceX engineers and LoFASM students and faculty, SpaceX and CARA have joined forces to create the Spacecraft Tracking and Astronomical Research into Gigahertz Astrophysical Transient Emission (STARGATE) facility: a public-private partnership pursuing radio-frequency research and technology innovation. As a result of LoFASM and STARGATE, CARA has been singled out as the first center of excellence for the newly-formed UT Rio Grande Valley (formed from the merger of UT Brownsville and UT Pan American). The UT system chancellor has recognized CARA for its key role in the creation of a research culture in South Texas.

Technology Transfer

(a) (b)

Figure 1: (a) The antenna configuration of a single Low-Frequency All-Sky Monitor (LoFASM) station. Each LoFASM station consists of two concentric rings of 6 dipole antennas, forming a hexagram with inner radius 441 cm and outer radius 764 cm. (b) (Upper picture) A map depicting the locations of all four LoFASM stations across the continental United States. (Lower Picture) An image of the 12 antennas installed at the LoFASM I site in Port Mansfield, Texas.

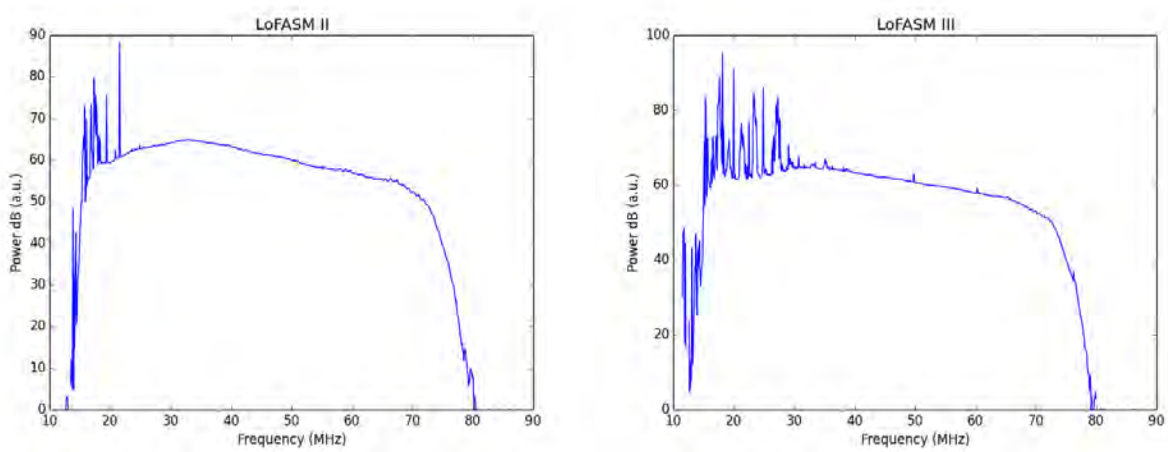

Figure 2: Sample power spectra from two LoFASM stations. The y-axes are uncalibrated power plotted in decibels. The x-axes are frequency in MHz. Both spectra show substantial terrestrial noise at low frequency, along with isolated lines of interference at higher frequencies. Identifying and avoiding or suppressing these noise artifacts will be key in allowing LoFASM to achieve its optimum sensitivity.

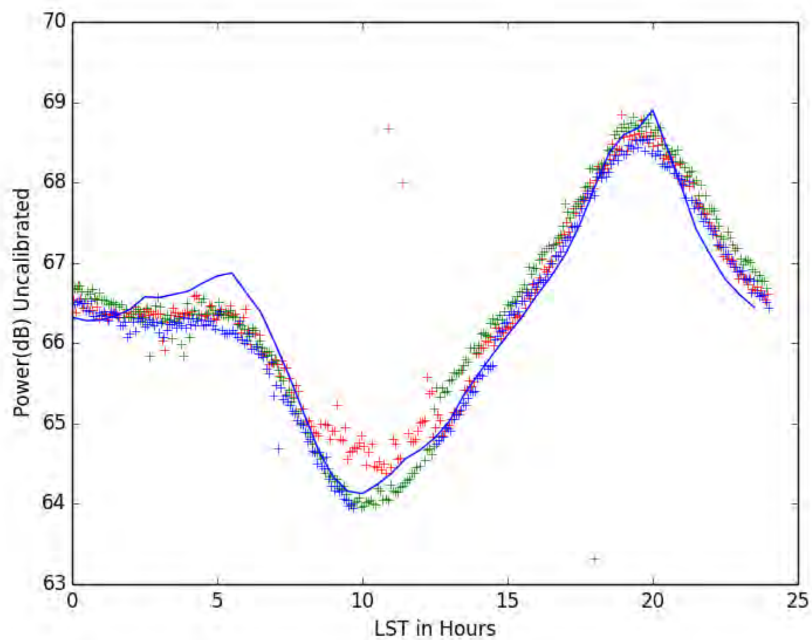

Figure 3: First steps towards a sensitivity estimate for LoFASM, showing the variation in received power at one station over three sidereal days. The vertical axis is uncalibrated power, and the horizontal axis is local sidereal time in hours. Pluses represent LoFASM data, showing total power within a clean frequency band integrated over short-duration segments over the course of three days: each day's data is plotted in a different color. The solid line is a model for the emission from the Galaxy averaged over the LoFASM beam at any instant in sidereal time. The close agreement shows that LoFASM is sensitive to, and thus ultimately limited by, the broadband radio background of the Galaxy.